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EVALUATION OF ANCHOR GROUTING AND BEARING PAD MATERIALS FOR USE IN TRANSMISSION LINE CONSTRUCTION AT LOW TEMPERATURES

FIELD EVALUATION OF ANCHOR GROUTS: DRILLING AND ANCHOR INSTALLATION

Report No. 88-135-K

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ABSTRACT

In 1987, a laboratory investigation was undertaken to assess anchor grouting materials, suitable for use at sub-freezing temperatures, for the construction of transmission lines. Part of this investigation included carrying out field trials (ie, rock anchor pullout tests) using the most promising grouts identified in the laboratory study. These pullout tests were conducted in May 1988, at a site near Lennox TGS. The purpose of this report is to summarize the rock drilling procedure and subsequent installation (grouting) of the anchor rods.

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EVALUATION OF ANCHOR GROUTING AND BEARING PAD MATERIALS FOR USE IN TRANSMISSION LINE CONSTRUCTION AT LOW TEMPERATURES

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1.0 INTRODUCTION

In 1987, an investigation was undertaken to assess anchor grouting materials, suitable for use at sub-freezing temperatures, for the construction of transmission lines. The initial phase of the program involved a laboratory assessment of various proprietary polymer grouting materials. From this study, four materials were identified which demonstrated good potential for field applications/1/. These four materials were then subjected to full-scale field rock anchor pullout tests in order to verify their in-situ performance. As well, "Anchortite 21-30 FS", a product that was approved for field use in a similar laboratory assessment program conducted in 1986/2/, and a Type 10 Portland cement grout were tested. These pullout tests were carried out at a site near Lennox TGS (see Figure 1) and the purpose of this report is to summarize the rock drilling procedure and subsequent installation (grouting) of the rock anchors.

2.0 DESCRIPTION OF THE TEST PROGRAM

The pullout tests were conducted using 35 mm (1-3/8 in) diameter, 827 MPa (120 ksi) yield strength, Dywidag deformed bars grouted in rock to depths of 305 mm (12 in), 508 mm (20 in), and 915 mm (36 in). Each hole diameter was 57 mm (2-1/4 in). A list of the grouts that were tested is provided in Table 1, and in Table 2 is a summary matrix of all tests conducted.

A sketch showing the layout of the holes is shown in Figure 2. The 46 holes were arranged in 5 rows spaced 6.1 m (20 ft) apart. The spacing between the holes within each row was calculated assuming an inverted right angle rock failure cone for each embedment. Also, given in Figure 2 are the hole identification numbers that will be referred to in subsequent sections.

Since these tests were designed to assess each grout's performance, failure of the anchor rod or rock was not desired. To prevent rod failure, high strength (827 MPa, 120 ksi) deformed bars were used. These bars have surface deformations conforming to ASTM A 615 (ie, that of standard reinforcing), and therefore, the development of bond will be similar to that of regular reinforcing bars. In an attempt to preclude rock failure, the anchor holes were drilled 254 mm (10 in) deeper than the required embedment depth. Therefore, for a 305 mm (12 in) embedment, the holes were drilled to a depth of 559 mm (22 in) and only the bottom 305 mm (12 in) of the hole was filled with grout. Similarly, for the embedment depths of 508 mm (20 in) and 915 mm (36 in), the holes were drilled 762 mm (30 in) and 1168 mm (46 in), respectively.

Another important aspect of the field trials were comments made by members of the construction crew regarding the handling and use of each material. These comments were noted and are discussed in Section 4.3.

3.0 ANCHOR INSTALLATION

3.1 Drilling

During the week of March 14 to 18, 1988, the 57 mm (2-1/4 in) diameter holes were drilled through a layer of overburden into the bedrock using an impact rotary drill equipped with a Star bit. The layout of the holes and their nominal depths are detailed in Figure 2, and in Tables 3, 4 and 5, the actual drilled depths are reported. The overburden varied in depth between 203 mm (8 in) and 610 mm (24 in), the top 152 mm (6 in) to 254 mm (10 in) being frozen. To reveal the drilled hole at the rock/overburden interface,a 610 mm (24 in) diameter area of overburden was excavated around each hole (see Figure 3). The holes were cleaned out by blowing compressed air into each hole to remove debris and free water that had collected during the drilling and excavating operations. All holes were then capped to await grouting.

A visual examination of the interior of the holes was conducted and the following observations were made:

i) Surface run-off water and subsurface water continually collected in many of the holes. Therefore, it was decided that all holes be re-cleaned immediately before grouting the anchors.

ii) The rock near the top of the holes (ie, only approximately the top 254 mm (10 in) was clearly visible) was fractured and thinly bedded.

iii) The sides of the holes appeared contaminated with rock flour, loose rock and wet soil.

3.2 Grouting

Prior to grouting, all holes were re-examined and re-cleaned and the condition of each is summarized in Tables 3, 4, and 5. The grouting procedure used is as follows:

i) Each grout was proportioned according to the manufacturer's recommendations (see Table 6) and was mixed with a jiffler mixer for at least 3 minutes.

ii) The grout was then poured into the hole and a 35 mm (1-3/8 in) diameter anchor rod inserted.

iii) Each anchor rod was maintained in a vertical position until the grout had set by wedging wooden shingles into the hole around the rod (see Figure 4).

This work was conducted between March 21 and 23, 1988, inclusive.

Table 3 summarizes all anchors that were grouted to nominal depths of 305 mm (12 in), and similarly Tables 4 and 5 summarize the anchors grouted to depths of 508 mm (20 in) and 915 mm (36 in), respectively. In these tables, the hole identification numbers are cross referenced with the particular anchor grout used, the actual drilled depth of holes, actual grouted lengths, ambient temperatures during grouting, and comments about the condition of each hole just prior to grouting.

4.0 TEST RESULTS/OBSERVATIONS DURING GROUTING

4.1 Temperature Rise

Thermocouples were installed on the embedded portion of some selected bars to measure the temperature rise of the various grouts. These results are reported in Table 7 and some observations are summarized as follows:

i) The ground temperature varied between 3° and 4°C at 508 mm (20 in) below the rock surface.

ii) Initial grout temperatures (except for the cement grout) ranged from -8° to -5°C. The initial cement grout temperature was 9°C.

iii) The time required for each grout's initial temperature to achieve equilibrium with ground temperature (3° to 4°C) varied for each as follows:
- Pronto 12 required approximately 2.5 hours

- Lokset required approximately 1.9 hours. However, the grout temperature actually exceeded the ground temperature at 0.58 hours (9°C) and 0.92 hours (7°C)
- Anchortite 21-30 FS required approximately 6.5 hours
- LT Anchor required approximately 3.75 hours
- Concressive 2010/2020 temperature after 1.25 hours exceeded ground temperature (7°C)
- Cement grout initially started at 9°C and still had not set after 24 hours

4.2 Compressive Strength Tests

On the days when the anchors were installed (grouted), samples of each grout were also used to cast standard (3 in x 6 in) compressive strength test cylinders. Six cylinders were made from each grout. These cylinders were field cured for 2 days (ie, the duration of the grouting operation), and subsequently, brought to the Civil Research laboratory where they were stored in a 23°C, 50% relative humidity environment until testing. Three cylinders of each material were tested at 28 days, and the remaining cylinders were tested on the day(s) of the anchor pullout tests. At the time of writing, only the results from the 28-day tests were available, and these are summarized in Table 8.

4.3 Comments on Handling the Grouts

In general, no major difficulties were encountered with handling and using the grouts. Specific comments are as follows:

i) Pronto 12
- material easy to mix
- material workable; however, not pourable
- material requires adjustment to the mix proportions to achieve a pourable consistency

ii) Lokset
- material easy to mix, flowable and poured easily into the holes

iii) Anchortite 21-30 FS
- material difficult to mix
- material workable; however, not pourable
- material requires adjustment to the mix proportions to achieve a pourable consistency

iv) LT Anchor
- material easy to mix, very flowable and poured easily into the hole

v) Concressive 2010/2020
- material easy to mix, very flowable and poured easily into the hole

vi) Type 10 Cement
- material initially flowable, but thickened rapidly
- material had not set in 24 hours

5.0 SITE ROCK CHARACTERISTICS

Two 1219 mm (48 in) long rock cores were drilled. The location of these boreholes is shown in Figure 2, and the borehole logs and compressive strength test data for each location are reported in Appendix A.

In general, the upper 914 mm (36 in) of the rock is described as being a pale grey, medium grain limestone with shaley partings. The shaley partings appear weathered. Below this level (ie, 914 to 1219 mm, 36 to 48 in), the rock is a shaley limestone with a "bird's eye" (ie, speckled) texture. The unconfined compressive strengths of the rock from borehole numbers 1 and 2 were 93.4 (13,553 psi) and 107.0 MPa (15,515 psi), respectively. The results from these boreholes are in agreement with an assessment of the rock at Lennox TGS that was made in an earlier anchor pullout study/3/. In this assessment, the rock was described as being a thinly bedded limestone (Trenton Limestone) with a range of shear strength values from 36 kPa (758 psf) to 105 kPa (2190 psf).

6.0 CONCLUDING REMARK

As part of an investigation assessing various proprietary anchor grouts for use at sub-freezing temperatures, a total of 46 rock anchors were installed using six different grouts at a location near Lennox TGS. The anchors were installed at three different embedment depths, and each was load tested to assess the in-situ performance of all grouts. The load tests were conducted over a two week period commencing May 9, 1988, and these tests are documented in a separate report/4/.

7.0 ACKNOWLEDGMENTS

The principal funding for this study was provided by the Transmission Lines Programs and Design Departments and is gratefully acknowledged. As well, the assistance of the construction field crew, which consisted of Mr. C. Sauter (Construction Engineer), Mr. B. Fournier and Mr. S. Crosbie, is appreciated. Appreciation is also extended to the engineering and technical support staff of the Civil Research Department, and particularly to Mr. D. Aita for his assistance in supervising the drilling operation and for his contribution in preparing this report.

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TABLE 1

GROUTS

Grout Type	Product Name	Supplier
Modified Polyester/ Acrylate	Pronto 12	Sika Canada Limited
Vinyl Ester	LT Anchor Grout	Cappar Limited
Polyester	Lokset	Fosroc
Methyl Methacrylate	Concressive 2010/2020	Adhesive Engineering
Polyester	Anchortite 21-30FS	Celtite
Cement	Type 10 Portland Cement (W/C = 0.4)	Laboratory Standard

TABLE 2

SUMMARY OF TESTS

Product	No. of Tests at each embedment		
	305 mm	508 mm	915 mm
Pronto 12	3	3	2
LT Anchor Grout	3	3	2
Lokset	3	3	2
Concressive 2010/2020	3	3	2
Anchortite 21-30 FS	3	3	2
Type 10 Portland Cement (W/C = 0.4)	2	2	2

TABLE 3

INFORMATION FOR ANCHORS GROUTED TO A NOMINAL 305 mm LENGTH

Hole I.D.	Grouting Material	Hole Depth (mm)	Distance Between Top of Rock and Grout (mm)	Grouted Length (mm)	Ambient Temp (°C)	Grout Temp after Mixing (°C)	Remarks
1	Pronto 12	533	273	260	-12	-7	Sides of hole wet; less than 6 mm of water at base of hole
2		533	311	241	-12	-7	Sides of hole wet; damp at base of hole
3		546	292	254	-12	-7	Sides of hole wet; damp at base of hole
4	Lokset	572	267	305	-10	-7	Sides of hole wet; damp at base of hole
5		559	260	299	-10	-7	Sides of hole wet; damp at base of hole
6a		540	241	299	-10	-7	Sides of hole wet; less than 6 mm of water at at base of hole
7	Anchortite 21-30 FS	559	254	305	-10	-6	Sides of hole wet; damp at base of hole
8		546	216	330	-10	-6	Sides of hole wet; damp at base of hole
9		565	260	305	-10	-6	Sides of hole wet; damp at base of hole

TABLE 3 Continued

INFORMATION FOR ANCHORS GROUTED TO A NOMINAL 305 mm LENGTH

Hole I.D.	Grouting Material	Hole Depth (mm)	Distance Between Top of Rock and Grout (mm)	Grouted Length (mm)	Ambient Temp (°C)	Grout Temp after Mixing (°C)	Remarks
10	LT Anchor	578	235	343	-7	-8	Sides of hole wet; damp at base of hole
11		527	210	318	-7	-8	Sides of hole wet; 25 mm of water at base of hole
12		533	203	330	-7	-8	Sides of hole wet; 12 mm of water at base of hole
13	Concressive 2010/2020	546	165	381	-4	-5	Sides of hole wet; less than 6 mm of water at base of hole
14		514	203	311	-4	-5	Sides of hole wet; less than 6 mm of water at base of hole
15		540	229	311	-4	-5	Sides of hole wet; 25 mm of water at base of hole
A	Type 10 Cement	597	279	318	-3	+9	Sides of hole wet; 203 mm of water at base
B		584	254	330	-3	+9	Sides of hole wet; 101 mm of water at base

Notes: 1) Pronto 12 and Lokset were used on March 21; the remaining grouting materials were used on March 22
2) The diameter of all drilled holes was 57 mm (2-1/4 in)
3) The length of all anchor rods used for these holes was 711 mm (28 in)

TABLE 4

INFORMATION FOR ANCHORS GROUTED TO A NOMINAL 508 mm LENGTH

Hole I.D.	Grouting Material	Hole Depth (mm)	Distance Between Top of Rock and Grout (mm)	Grouted Length (mm)	Ambient Temp (°C)	Grout Temp after Mixing (°C)	Remarks
16	Pronto 12	762	241	521	-12	-7	Sides of hole wet; less than 6 mm of water at base of hole
17		749	241	508	-12	-7	Sides of hole wet; 6 mm of water at base of hole
18		749	203	546	-12	-7	Sides of hole wet; less than 6 mm of water at base of hole
19	Lokset	743	203	540	-10	-7	Sides of hole wet; 64 mm of water at base of hole
20		724	229	495	-10	-7	Sides of hole wet; less than 6 mm of water at base of hole
21		749	241	508	-10	-7	Sides of hole wet; less than 6 mm of water at base
22	Anchortite 21-30 FS	718	235	483	-10	-6	Sides of hole wet; damp at base of hole
23		718	235	483	-10	-6	Sides of hole wet; damp at base of hole
24		743	235	508	-10	-6	Sides of hole wet; damp at base of hole

TABLE 4 Continued

INFORMATION FOR ANCHORS GROUTED TO A NOMINAL 508 mm LENGTH

Hole I.D.	Grouting Material	Hole Depth (mm)	Distance Between Top of Rock and Grout (mm)	Grouted Length (mm)	Ambient Temp (°C)	Grout Temp after Mixing (°C)	Remarks
25	LT Anchor	724	241	483	-7	-8	Sides of hole wet; 6 mm of water at base of hole
26		724	241	483	-7	-8	Sides of hole wet; 178 mm of water at base of hole
27		762	235	527	-7	-8	Sides of hole wet; damp at base of hole
28	Concressive 2010/2020	762	235	527	-4	-5	Sides of hole wet; 508 mm of water at base of hole
29		749	248	502	-4	-5	Sides of hole wet; less than 6 mm of water at base of hole
30		743	222	521	-4	-5	Sides of hole wet; less than 6 mm of water at base of hole
E	Type 10 Cement	699	159	540	-3	+9	Sides of hole wet; 203 mm of water at base
F		775	305	470	-3	+9	Sides of hole wet; 102 mm of water at base

Notes: 1) Pronto 12 and Lokset were used on March 21; the remaining grouting materials were used on March 22
2) The diameter of all drilled holes was 57 mm (2-1/4 in)
3) The length of all anchor rods used for the above holes was 915 mm (36 in)

TABLE 5

INFORMATION FOR ANCHORS GROUTED TO A NOMINAL 915 mm DEPTH

Hole I.D.	Grouting Material	Hole Depth (mm)	Distance Between Top of Rock and Grout (mm)	Grouted Length (mm)	Ambient Temp (°C)	Grout Temp after Mixing (°C)	Remarks
31	Pronto 12	1137	210	927	-12	-7	Sides of hole wet; 38 mm of water at base of hole
32		1149	216	933	-12	-7	Sides of hole wet; 38 mm of water at base of hole
33	Lokset	1149	235	914	-10	-7	Sides of hole wet; 51 mm of water at base of hole
34		1143	229	914	-10	-7	Sides of hole wet; 241 mm of water at base of hole
35	Anchortite 21-30 FS	1162	305	857	-10	-6	Dry hole
36		1156	191	965	-10	-6	Sides of hole wet; damp at base of hole
37	LT Anchor	1143	229	914	-7	-8	Sides of hole wet; 51 mm of water at base of hole
38		1143	216	927	-7	-8	Sides of hole wet; 127 mm of water at base of hole

TABLE 5 Continued

INFORMATION FOR ANCHORS GROUTED TO A NOMINAL 915 mm DEPTH

Hole I.D.	Grouting Material	Hole Depth (mm)	Distance Between Top of Rock and Grout (mm)	Grouted Length (mm)	Ambient Temp (°C)	Grout Temp after Mixing (°C)	Remarks
39	Concressive 2010/2020	1118	191	927	-4	-5	Sides of hole wet; 356 mm of water at base of hole
40		1111	178	933	-4	-5	Sides of hole wet; 305 mm of water at base of hole
C	Type 10 Cement	1099	260	838	-3	+9	Sides of hole wet; 203 mm of water at base of hole
D		1149	279	870	-3	+9	Sides of hole wet; 76 mm of water at base of hole

Notes: 1) Pronto 12 and Lokset were used on March 21; the remaining grouting materials were used on March 22
2) The diameter of all drill holes was 57 mm (2-1/4 in)
3) The length of all anchor rods used for the above holes was 1321 mm (52 in)

TABLE 6

MIX PROPORTIONS OF GROUTS

Product	Resin (g)	Catalyst % mass of resin	Promoter % mass of resin	Fine Aggregate (g)	Aggregate/Resin Ratio
Pronto 12	3200	-	-	25,920	8.1 : 1.0
Lokset	5000	-	-	22,500	4.5 : 1.0
Anchortite 21-30 FS	4091	-	-	12,272	3 : 1.0
LT Anchor	3600	4	-	18,000	5.0 : 1.0
Concressive 2010/2020	1950	8.2	3.5	27,300	12.0 : 1.0
Type 10 Portland Cement	w/c = 0.4	-	-	-	-

TABLE 7

THERMOCOUPLE READINGS OF TEMPERATURE RISE IN GROUTED HOLES

Product	Hole I.D.	Ambient Temp (° C)	Elapsed Time After Grout Mixed(hr:min)	Temperature of Grout (° C)
Pronto 12	17 & 31	-12		Hole 17 & 31
			0	-7
			1 : 00	-5
			2 : 30	+4
			3 : 20	+4
			5 : 40	+4
Lokset	19	-10		Hole 19
			0	-7
			0 : 20	+4
			0 : 35	+9
			0 : 55	+7
			1 : 55	+4
Anchortite 21-30 FS	23 & 35	-10		Hole 23 Hole 35
			0	-6 -5
			1 : 25	+1 0
			6 : 30	+3 +3
LT Anchor	25 & 37	-6		Hole 25 & 37
			0	-8
			0 : 25	0
			3 : 45	+3
Concressive 2010/2020	39	-4		Hole 39
			0	-5
			1 : 15	+7
Type 10 Portland Cement	A,B,C,D	-2		Hole A,B,C,D,E,F
			0	+9

Notes: 1) The ground temperature was between 3° and 4°C 508 mm (20 in) below the rock surface

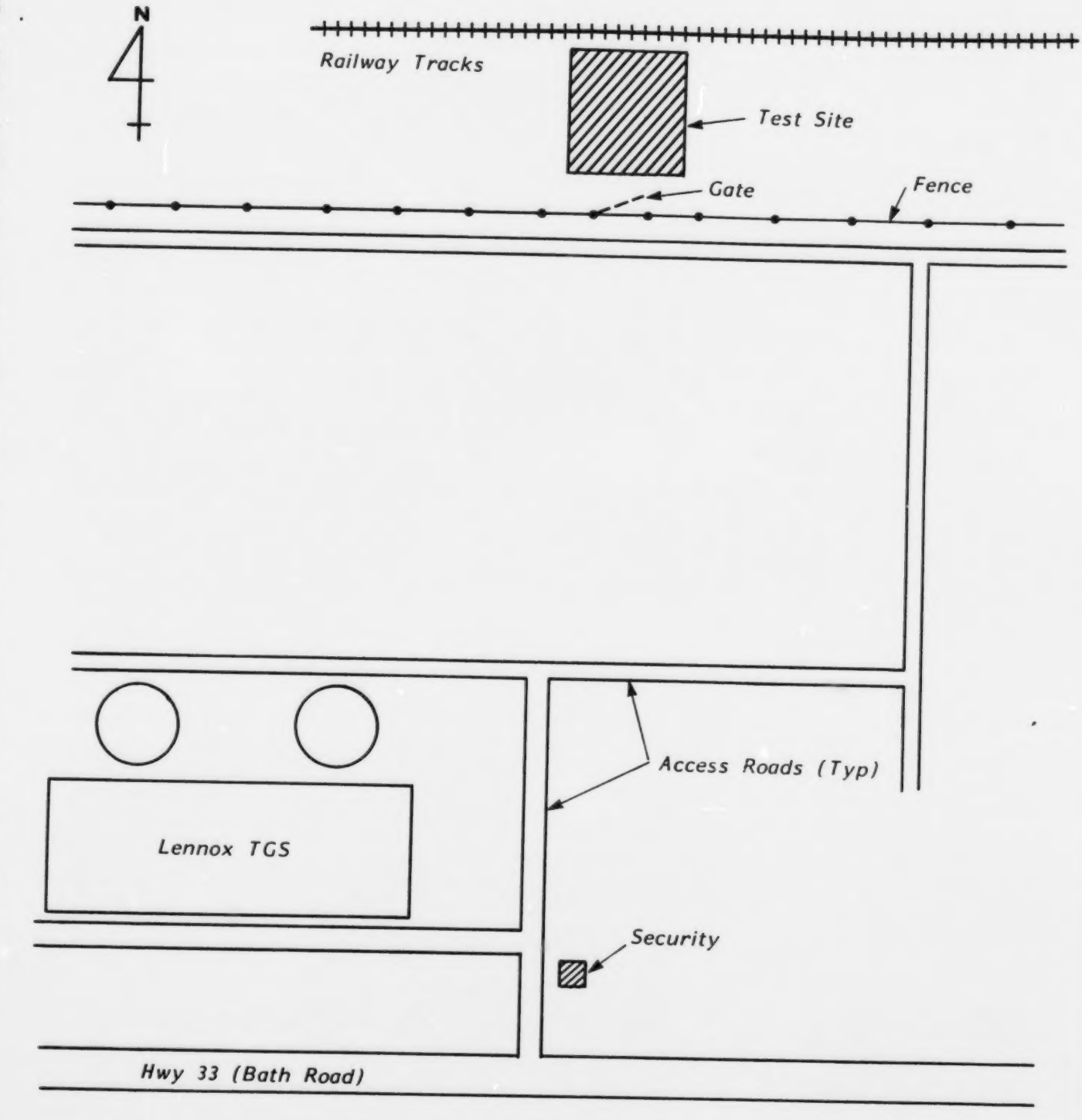
2) The thermocouples were located at 127 mm (5 in) and 178 mm (7 in) from the bottom of the 915 mm (36 in) and 1321 mm (52 in) anchor rods, respectively

TABLE 8

28-DAY COMPRESSIVE STRENGTHS

Product	28-Day Strength (MPa)
Pronto 12	83.6
Lokset	39.2
Anchortite 21-30 FS	77.8
LT Anchor	87.2
Concressive 2010/2020	42.5
Type 10 Cement	(1)

(1) Test cylinders for the Type 10 cement grout were not made due to the sub-freezing temperatures on the day of casting. The grout in the anchor hole had not set after 24 hours and similar problems were expected with cylinders. Compressive strength results for laboratory standard Type 10 cement at a water-cement ratio of 0.40 are generally 55 MPa at 28 days.

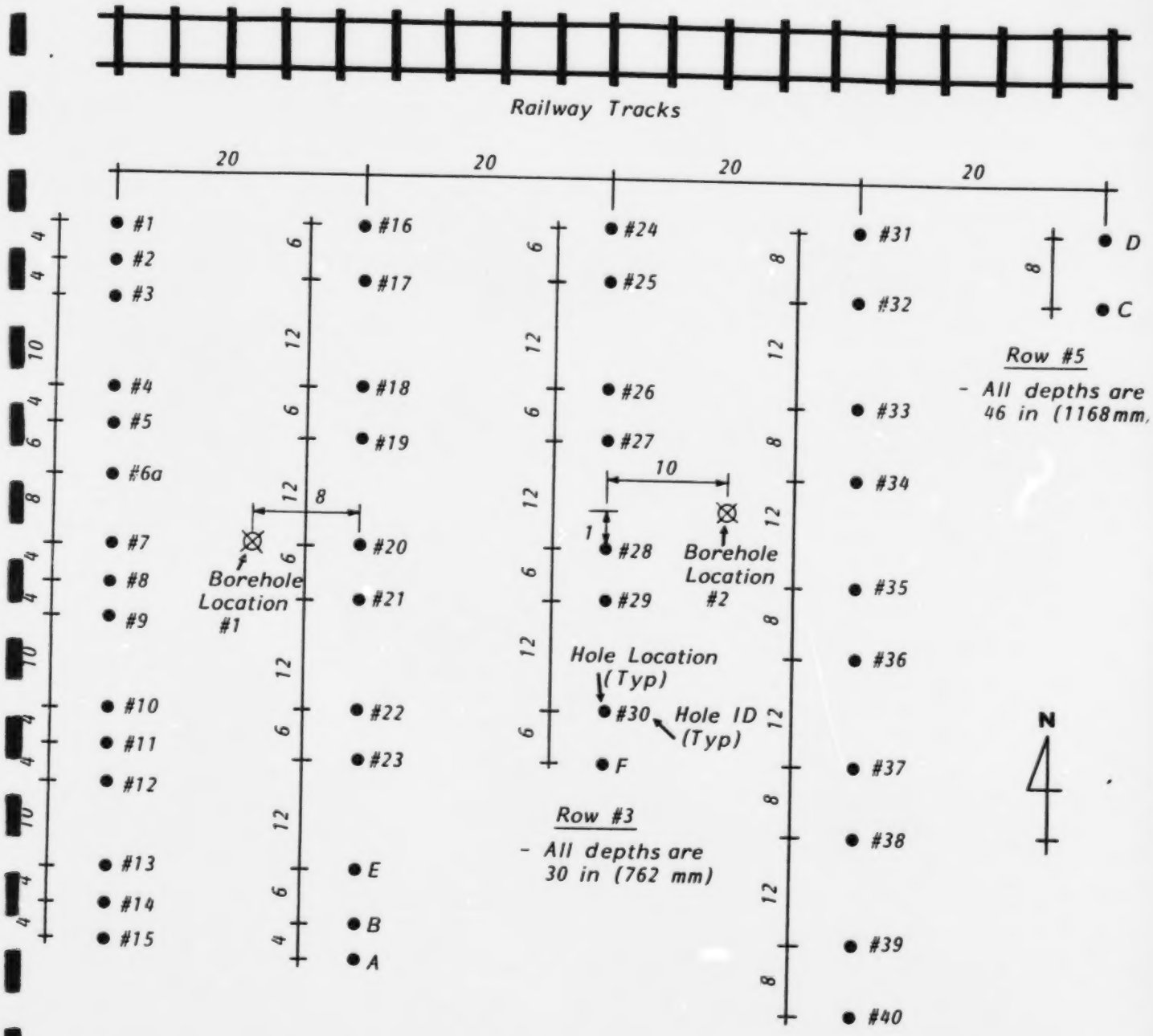


NOTE:

(1) Sketch not to scale.

FIGURE 1
TEST SITE LOCATION

88-135
177133-RD



Row #1

- All depths are 22 in (559 mm)

Row #2

- All depths except holes 'A' & 'B' are 30 in (762 mm)
- 'A' & 'B' depths are 22 in (559 mm)

Row #4

- All depths are 46 in (1168 mm)

NOTES:

(1) All dimensions are in feet unless otherwise noted.
(2) Sketch not to scale.

FIGURE 2
HOLE LAYOUT

88-135
177134-RD

FIGURE 3

OVERBURDEN EXCAVATED AROUND EACH ANCHOR HOLE TO EXPOSE ROCK SURFACE

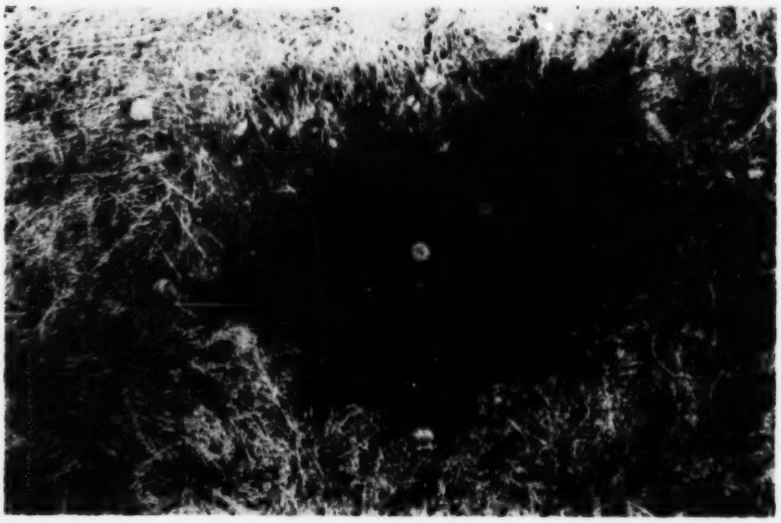


FIGURE 4

ANCHOR ROD SET IN PLACE

APPENDIX A

BOREHOLE DATA (1)

(1) Data taken from Ontario Hydro Research Division Report No. SR88-3-H

A.1 Borehole Number 1

A.1.1 Log

Depth	Description
0'0" - 1'1"	- overburden
1'1" - 3'7"	- pale grey, medium grain limestone with occasional shaley parting
	- the top 1' of core is badly broken, shaley partings appear weathered
	- soil occurs on some parting surfaces, but it is not certain whether this is naturally occurring or core was dropped in mud during handling
	- bedding is dipping from 0° to 10°
3'7"	- contact with lower unit, distinguished by weathered (blanched) appearance and several closely spaced joints in first 1" of lower unit
3'7" - 4'1"	- medium to dark grey, fine to medium grain shaley limestone exhibiting bird's eye texture

A.1.2 Compression Strength Results

Sample #1	Depth:	1'10" - 2'3"
	Average Diameter:	2.480"
	Average Height:	4.915"
	Area:	4.831 sq"
	Compressive Strength:	13,553 psi
	Failure Type:	Cone and Splitting

A.2 Borehole Number 2

A.2.1 Log

Depth	Description
0'0" - 0'10 1/2"	- overburden
0'10 1/2" - 2'11 1/2"	- pale grey medium grain limestone
0'11" - 0'12"	- closely spaced weathered bedding planes
2'11 1/2"	- contact with bird's eye limestone
2'11 1/2" - 4'11 1/2"	- bird's eye shaley limestone

A.2.2 Compressive Strength Results

Sample #1

Depth:	2'7 1/2" - 3'0"
Average Diameter:	2.479"
Average Height:	4.342"*
Area:	4.827 sq"
Compressive Strength:	12,912 psi
Failure Type:	Cone and Splitting

* Denotes the sample height was less than twice the diameter

Sample #2

Depth:	2'9" - 3'3"
Average Diameter:	2.480"
Average Height:	4.876"
Area:	4.831 sq"
Compressive Strength:	18,117 psi
Failure Type:	Cone and Splitting